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Beginning in 1992, the U.S. Army Corps of Engineers' (USACE) Lower Mississippi Valley Division (LMVD) began to examine the use of ECDIS for support of their river engineering and construction mission on the Lower Mississippi River. LMVD envisions the use of ECDIS for navigation aboard all Division floating plants. The Division has joined a coordinated testbed project and has implemented an experimental system aboard the USACE *Motor Vessel Mississippi*. Although USACE has no charting mission, survey data collected in support of engineering, construction, and maintenance activities can and has been used to produce electronic chart databases for ECDIS. Through LMVD's ECDIS and database development efforts, the use of ECDIS or less complex Electronic Chart Systems (ECS) for other users could be possible.

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ECDIS TEST AND DEMONSTRATION ON THE MISSISSIPPI RIVER

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ABSTRACT

Electronic Chart Display and Information System (ECDIS) activities currently being conducted address a variety of issues pertaining to navigation at sea, coastal areas, and various ports and harbors. An area that has received little attention has been inland waterways, such as the Mississippi, Missouri, and Ohio rivers. This may be because of some different requirements for navigation in such confined channels or because of fewer high profile incidents, such as collisions or groundings. However, the most probable reason is the lack of availability of nautical charts for inland waterways.

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BACKGROUND

The Lower Mississippi Valley Division (LMVD) of the U.S. Army Corps of Engineers (USACE) has the massive mission of maintaining the Lower Mississippi River for flood control and navigation. The St. Louis, Memphis, Vicksburg, and New Orleans Districts are engaged in various engineering, consruction, operations, and maintenance activities on approximately 1,200 miles of river from St. Louis to the Gulf of Mexico. These activities include surveying, dredging, and construction of levees, dikes, and revetments. To more effectively conduct this mission, the districts have integrated computer-aided design and drafting (CADD) in most aspects of analysis, planning, design, implementation, and maintenance. The districts are also adopting the highly accurate positioning technology, Differential Global Positioning System (DGPS), in field activities. To coordinate activities and take maximum advantage of this technology, the LMVD Hydrographic Survey Group was formed. The Survey Group has six Working Groups for the establishment of DGPS, use of DGPS in automation of revetment construction and bank grading, use of CADD in all aspects of river construction design, development of a Division-wide spatial database, and development of electronic charts to supplement or replace current navigation charts.

The Electronic Chart Work Group of LMVD decided in mid-1992 to demonstrate an electronic chart capability aboard the new *Motor Vessel Mississippi* during the 1993 Mississippi River Commission (MRC) High Water Inspection trip. This demonstration would be combined with the Differential Global Positioning System (DGPS) demonstration that was planned by the DGPS Work Group. Indeed, the two demonstrations would not only compliment, but be dependent upon each other. Within LMVD, the electronic chart concept arose from the real-time positioning/CADD System developed for revetment construction operations. This system uses real-time DGPS interfaced with a CADD system to direct construction barge positioning and produce real-time as-built drawings. The electronic chart system was envisioned as yet another application of the comprehensive digital engineering database for river engineering and construction. Use of this database in an electronic chart application would enable automation of some navigation functions, detailed project review onboard a river vessel, and possible as-built creation and/or updating on construction floating plant. For the 1993 MRC trip, LMVD obtained an Electronic Chart Display and Information System (ECDIS) and a less complex Electronic Chart System (ECS) for demonstration.

DGPS COVERAGE

The key development in LMVD that enables the use of electronic chart systems is the establishment of DGPS service. In 1990, LMVD districts began establishing reference stations with real-time broadcast of differential corrections. This service was initiated for meter-level positioning in hydrographic surveying, dredging, and river construction operations. Data were broadcast in UHF frequency from permanent stations at existing district radio communications stations and from mobile stations at survey control points on or near levees. The DGPS Work Group made plans to establish a dozen or more permanent UHF stations to produce continuous full-time coverage over the Lower Mississippi River. For the electronic chart demonstration, UHF data was broadcast from stations in Memphis and New Orleans.

At the same time, the U.S. Coast Guard planned to implement similar DGPS service along the entire U.S. coast using their radio beacon broadcast service. This system, which operates at a lower frequency than the planned LMVD service, was deemed to be inadequate for the USACE 3-meter, 1σ accuracy requirement. However, a pilot project was conducted in June 1993 near New Orleans to determine the accuracy attainable with an upgraded radio beacon station. These upgrades include use of a full wavelength dual frequency GPS receiver, increased data rate, and use of the new RTCM 104, Type 9 message format. Accuracy was found to be amazingly good; 1.3 meters, 2σ.

Since the radio beacon system was proven to meet USACE horizontal accuracy requirements for hydrographic surveys, USACE adopted the system for meter-level positioning. A Memorandum of Agreement between USACE and the Coast Guard enables cooperation on radio beacon service where common interests exist. In coordination with the Coast Guard, LMVD now plans to establish four radio beacon stations, one at each district office, to completely cover the Lower Mississippi River. The Coast Guard plans to use upgraded equipment, similar to that used in the pilot project, in all planned radiobeacon reference stations. Mobile reference stations will be used where the new high accuracy, centimeter level system, which requires higher data rate, is needed.

ECDIS TESTBED SYSTEM

Demonstration during the 93 MRC High-Water trip of an ECDIS based on a district or division engineering database was quickly found to be overly ambitious. An ECDIS with such compatibility does not exist, and development of such a system would require much more time than the available five months. Therefore, a system that would accept district CADD files with minimum reformatting effort, and that would be suitable for the technology demonstration, was needed. An Intergraph-based system that fulfills these requirements was found in another ECDIS project.

U.S. ECDIS Testbed Project

The U.S. ECDIS Testbed Project began in 1990 as a project to test the International Maritime Organization (IMO) Provisional Performance Standard (PPS) and the more recent Draft Performance Standard for ECDIS. The project is a joint government-industry-research institution program, with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Coast Guard (USCG) as the primary Federal partners, and the Marine

Policy Center at the Woods Hole Oceanographic Institute (WHOI) the Project Coordinator. Industry partners include Exxon Shipping, the American Petroleum Institute, and American Telephone and Telegraph (AT&T). The stated objectives of the testbed Project are:

1. Assist the Coast Guard in developing a U.S. position on the IMO PPS.

2. Test and evaluate the IMO PPS through the use of a testbed system in a range of scenarios.

3. Demonstrate the potential of ECDIS in marine environmental protection, safety of navigation, and effficient vessel operation.

4. Stimulate user and manufacturer interest in ECDIS.

The Intergraph Corporation was tasked to develop a testbed ECDIS, based on an off-the-shelf graphics work station, that would meet or exceed the IMO PPS. Additionally, Raytheon Marine is participating in the project by helping develop a digital radar interface to integrate a radar display with the ECDIS.

LMVD Participation

The LMVD became interested in the testbed project because the Intergraph-based testbed system has functions that would be suitable to a demonstration of the technology on the Mississippi River. Although LMVD engineering databases are mostly Intergraph design (DGN) file or Modular GIS Environment (MGE) based, they are not compatible with the DX-90 data transfer format used by the testbed system. However, LMVD survey CADD files could be re-formatted (with considerable effort) to "fit" the Testbed System. This experimental ECDIS also featured extensive electronic chart capability that would provide an excellent insight into this new technology.

LMVD, and USACE, therefore became participants in the U.S. ECDIS Testbed Project. Such participation entails a financial contribution for the ECDIS development, use of the ECDIS according to International Maritime Organization (IMO) Provisional ECDIS Standards (where possible), and report of test results to the testbed partners.

SYSTEMS IMPLEMENTATIONS

Intergraph Testbed System

The ECDIS developed in the testbed project runs on an Intergraph Unix-based computer workstation. The vessel position is updated every 4 seconds and the screen can be configured to display various navigation information. This information includes latitude/longitude,course-over-ground/speed-over-ground, range, bearing, reverse bearing, and estimated time of arrival. Data for selected features, such as information for a buoy or a critical depth contour, can also be displayed. A radar interface and overlay capability has been developed for applications by other testbed project participants, although the capability was not demonstrated in this test.

Tru-Chart ECS

The Tru-Chart electronic chart software package by Resolution Mapping, Inc. (formerly Maptech) is a PC-based system that interfaces with a Loran-C or GPS receiver. The system is commercially available with scanned NOAA charts of the coastal U.S. and Great Lakes. Like the ECDIS, the Tru-Chart ECS can be interfaced to various sensors; such as speed log, gyrocompass, and depth sounders; from specific vendors (none of which are on the *Mississippi*). The user can enter planned routes with up to 100 waypoints, set track samples based on time or distance, and set alarms and marks. A major difference between the ECDIS and ECS is the Tru-Chart system uses a raster, rather than vector, electronic chart (EC).

Database Development

The absence of a comprehensive digital database for the Mississippi River makes the implementation of any ECDIS or ECS a challenging project. Although CADD survey data files for the Mississippi River are available in Intergraph DGN format, they do not have a common data structure, scale, nor content. Thus, the CADD files from the districts were reformatted so that data elements maintained common levels. In the files where depth contours did not exist, such features were generated and color-filled. Common buoy symbols were entered, the database was converted to the North American Datum of 1983, and an information database was generated from the graphics elements. Finally, the reformatted CADD files were converted to DX-90, the data exchange format required by the ECDIS.

For the Tru-Chart ECS, the DX-90 files were converted back to Intergraph DGN files and divided into plates, which were 1:8,000 scale sections that fit into the 19-inch monitor. Control points for each corner and a color depth contour legend were added to each plate. Raster PCX files were then created for each plate and sent to Resolution Mapping to create a Tru-Chart EC for the Mississippi River. A total of 110 plates covering 96 miles of river were produced.

Sensor Interfaces

Although the ECDIS and ECS both use National Maritime Electronics Association (NMEA) standards for sensor inputs, customized interfaces were required to combine and use the associated systems. The Intergraph Testbed System required, at a minimum, position and heading input, while the Tru-Chart system only required position data. The testbed system also required all sensor data to be input through a single serial port. Therefore, data from the positioning system were split and sent to both demonstration systems. GPS position and gyrocompass data were combined into a single data stream for input to the testbed system.

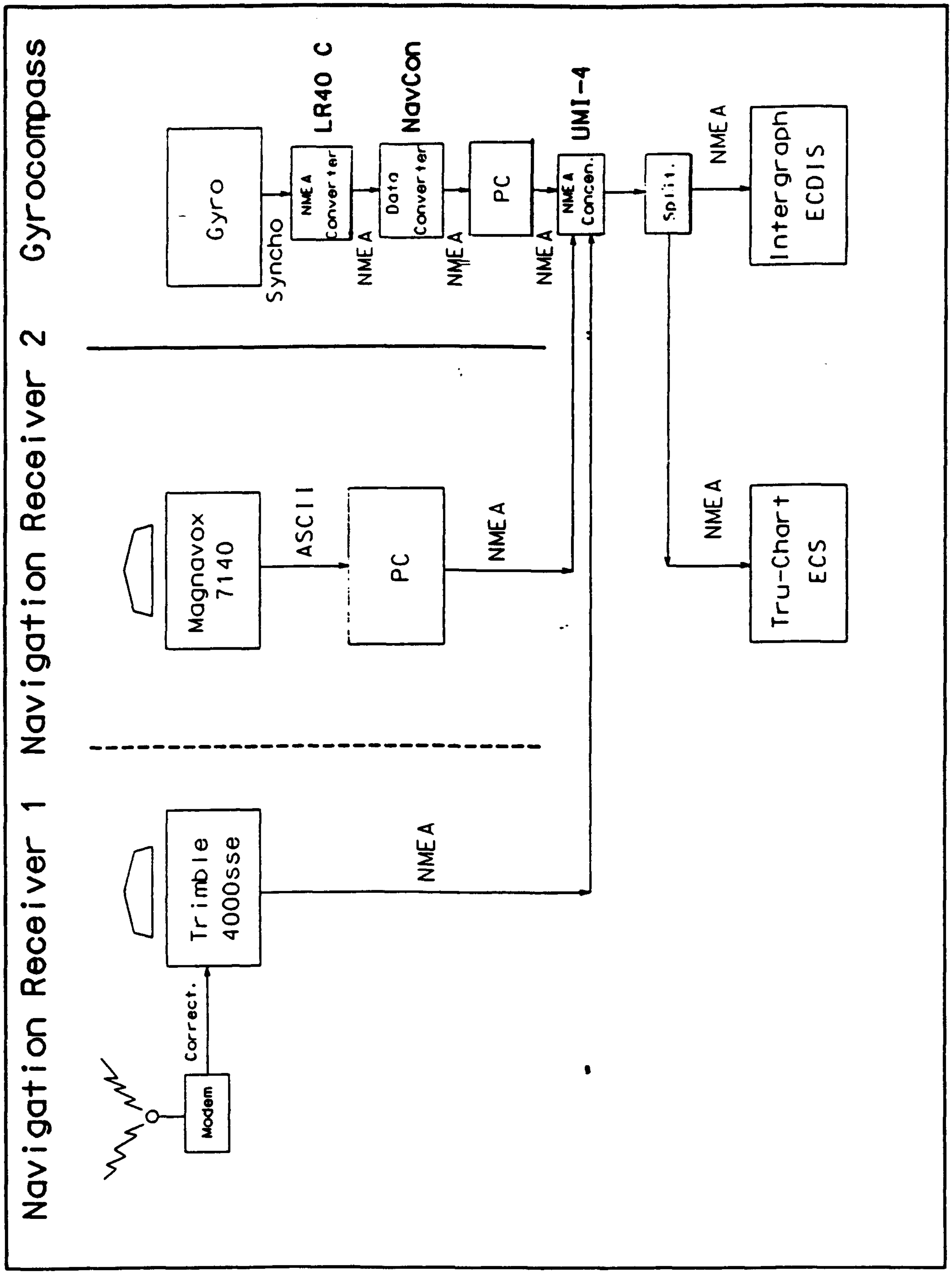
Other implementations of the testbed system by other testbed project participants used mostly Magnavox GPS and data concentrator equipment. However, this demonstration was to use Trimble DGPS equipment and some devices that do not output in NMEA format. Therefore, an interface configuration using third party devices and in-house developed data formatting software was designed and developed, as shown in the figure on the following page.

Navigation Receiver 1: During the MRC Inspection Trip, the ECDIS/ECS demonstrations were to be combined with the DGPS demonstration that would illustrate the planned Mississippi DGPS Network (MDN). Indeed, the two technologies are mutually dependent, since ECDIS/ECS is needed for a meaningful presentation of DGPS and the electronic charting application is useless without high accuracy positioning. A Trimble SSE receiver with a Motorola radio and modem were used for the onboard DGPS. The Trimble unit outputs at 4800 baud data rate, in NMEA-0183 formats; which were required by the ECDIS and ECS.

Navigation Receiver 2: Since full DGPS coverage for the MRC Trip was not expected, an alternate means of accurate positioning was needed. Positioning of 10-15 meters accuracy throughout the MRC Trip was thus obtained with a keyed Precise Positioning Service (PPS) receiver. A Magnavox 7140 military unit was loaned by the Tactical Positioning Branch at the Topographic Engineering Center (TEC) and was used during all demonstration segments where DGPS was not available. The keying procedure to enable use of the encrypted positioning code was performed at TEC shortly before the MRC Trip. Since re-keying is not needed for approximately two weeks, 15 meters positioning accuracy was available throughout the five day trip. A trip longer than two weeks would present a logistics problem, since security requirements dictate that the PPS receiver be keyed at a secure location.

The 7140 Receiver can output data in ASCII format, although not in the NMEA standard. A PC was used with custom software to re-format the ASCII data into NMEA-0183 GLL format.

Gyrocompass: The Sperry Marine MK-37 gyrocompass on the *Mississippi* outputs in a 4-wire synchro analog output. A Lehmkuhl LR40-C Digital Repeater, also from Sperry Marine,



Sensor Interface Configuration

was obtained to convert the data into digital NMEA HDT format. The Lehmkuhl also features a digital heading display and calibration input capability. A NAVCON Data Converter from Mericom Electronics was used to convert the RS-422 output from the Lehmkuhl into the required RS-232 output. The Lehmkuhl was expected to outputdata at 4800 baud, although when tested, was found to output at 9600 baud. A PC with custom software was thus used to produce the output at the required rate.

ECDIS and ECS Inputs: The NMEA data from the gyrocompass and the navigation receiver were combined into a single data stream by a UMI-4 Data Concentrator from Mericom Electronics. The data were output in NMEA-0183 VTG format. Although the Tru-Chart system does not use heading data from the gyrocompass available, the ECS did accept the combined data stream from the UMI-4. A modem splitter was used to send data to the ECDIS and ECS.

Systems Demonstrations

During the MRC trip 26-29 April, the Testbed and Tru-Chart systems functioned well. DGPS, producing 1 to 2 meter accuracy, was available ans used in the New Orleans and some parts of the Memphis Districts. Elsewhere, 10 to 15 meter positional accuracy was obtained with the keyed PPS GPS receiver.

Numerous observers, which included O-7 level officers from the Army, Navy, Coast Guard, and NOAA, examined the demonstration systems during the trip. Most were impressed and had favorable comments. Captain Chuck Keistler of the *M/V Mississippi* also examined the test systems and provided valuable user comments.

ANALYSIS

The EC for this project was developed from vector-based CADD survey files from the districts. Development of theECwas the most significant effort for this demonstration project. Indeed, creating and updating an accurate and consistent database are, by far, the biggest challenges to consider for river ECDIS/ECS activities.

Chart Content

The demonstration database included only a limited number of features, since additional data could not be collected and incorporated with the short development time. However, the features that were included were those deemed to be most important for navigation. Color-coded contours, referenced to Mean Lower Low Water Reference Plane (MLLWRP), were displayed at 0, 5, 10, 20, and 30 foot intervals. A contour for above MLLWRP and for below 30 feet were also displayed. The survey soundings used to generate the contours were included. This EC, used in both the Testbed and Tru-Chart systems, in vector and raster forms, respectively; has the most bottom topography information of any ECDIS/ECS known to exist. Theoretically, a vessel pilot could use this information to navigate over a broader reach of the river. This could enable optimum vessel operation with respect to river currents and identification of "bail-out zones" if the vessel must suddenly deviate from the defined channel due to traffic.

Additional features and database developments that are needed are:

Contour Adjustment: The most significant problem of the demonstration EC was the discrepancy between MLLWRP and the existing river stage. To determine the actual depths during use, the user had to add the current river stage to the displayed contours. Ideally, the system should adjust the displayed contours based on the current river stage entered automatically or by the user. With little development effort, an ECDIS could be modified to adjust the contour values, although this would create odd contour levels (i.e. 3-8-13-18 feet intervals). Maintaining fixed contour intervals (i.e. 0-5-10-15 feet intervals) regardless of the river stage involves re-generation of the contours, which can be a long and computationally intensive process and can not

The alternative is to generate a dense set of contours in the development of the ECD. When used in the ECDIS, the appropriate contours based on the water level would be displayed.

Buoy Updating: Most aids to navigation; including buoys, day markers, and river gages; were also included on the demonstration ECD. Many of the actual buoy positions did not coincide with theECpositions, which was not surprising since the buoys are frequently displaced by currents. This illustrated the need for easy and rapid means to update the charted buoy positions. As updated buoy information is available from surveys or other sources (i.e. USCG), the ECDIS should be able to read the data from an update file and modify theECaccordingly. Currently, for both the Testbed and Tru-Chart Systems, the ECD must be re-generated to enter new buoy information. The vessel captain should also have the capability to easily update buoys as discrepancies are found, during navigation and between charted and actual positions.

Bridge Information: Other database information needed for river navigation is data for obstructions, primarily bridges. Accurate representation for the bridge piers is needed to aid the pilot in aligning the vessel for passage through the narrow confines. This is particularly important during periods of low visibility. The user should be able to summon further information, such as the vertical clearance and drawspan opening information. Note that this requires coordination with other agencies, such as state highway departments and railroad companies, to obtain such data.

Overbank Features: The demonstration EC featured overbank information in the New Orleans District area. This data included roads, buildings, industrial sites, and some utilities. From the perspective of navigation, the need for such information is questionable. Indeed, the ECDIS that USCG has found to be most useful in their Test and Evaluation effort has no overbank features. However, such data are certainly useful if the ECDIS is being used for Inspection Trip presentations. Vessel pilots might also find the features useful as references in navigation. The inclusion of overbank data clearly makes the database development task more complex. For further database developments, the use of the ECDIS or ECS should be considered, i.e. navigation or project review, and further input from the users should be considered.

Chart Updating

The means of updating an EC with more current and accurate information, as such data becomes available, is one of the most significant issues in ECDIS or ECS. The issue is even more critical in waterways such as the Mississippi River, where bottom topography is so dynamic. The Southwest Pass in Louisiana, which is the busiest shipping lane in the U.S., is surveyed weekly to follow shoals that are forming or shifting and that could be a danger to shipping. EC updates in such situations would probably need to be sent to users via telemetry links, perhaps by satellite or by the same radio link that transmits DGPS data. The latest task order in the ECDIS Testbed Project investigates this issue, and USACE intends to participate in these activities.

Data Standards

Within LMVD, the River Database Working Group has the goal of developing a division-wide spatial database for the Mississippi River system, based on existing data processing systems and database development work. Accomplishing this goal will enable accurate and efficient EC development, transfer and use within the division. Once an LMVD standard is established, a correspondance to other data exchange standards can be defined, and translation between the standards will be possible. Such capability will be essential if EC data are to be transferred to outside users, since a recognized Federal digital exchange standard must be used.

USACE has been investigating the DX-90 Data Exchange Standard promoted by NOAA and IHO. Through use of this standard, USACE hydrographic survey data could more accurately and efficiently be transferred to NOAA for use in their nautical charts.

Currently, NOAA is pursuing the development of an application profile under the Spatial Data Transfer Standard (SDTS), which has been designated Federal Information Processing Standard No. 173 (FIPS 173). This profile is based on the DX-90 standard and is intended for hydrographic data. If a demand for USACE EC data exists, on inland or coastal waterways, the DX-90 Profile under SDTS will give USACE an effective and accepted means under Federal requirements for providing such data.

CONCLUSION

The USACE LMVD has successfully demonstrated ECDIS and ECS on the Mississippi River. With the survey design files that are used in support of river engineering, construction and maintenance actvities, electronic charts with large scale and accurate contours have been produced. ECDIS and ECS demonstrations in 1993 used such electronic charts combined with positioning from DGPS (1-2 meter accuracy) and GPS (15 meter accuracy). Several needed modifications were identified; such as relating contours to the current river stage, addition of bridge piers and span clearances, update of buoy positions, and a quick and effective means of updating depth contours.

Within USACE, ECDIS can be very beneficial for navigation and project analysis on inland waterways. As has been determined in coastal ports and waterways, ECDIS can be a great benefit to the safety of navigation on inland waterways. As USACE continues test and development efforts in ECDIS and ECS, efficient and effective means of transferring technology and electronic chart data to outside users will be pursued.

REFERENCES

1. IMO Provisional Performance Standards for ECDIS, International Maritime Organization, April 1989.

2. Alexander, Lee, U.S. Coast Guard Test and Evaluation Program of ECDIS Performance Standards, presented to IMO/IHO HGE 13, Honefoss, Norway, 20-23 September 1992.

3. Alsip, D.H.; Butler, J.M.; Radice, J.T.; Implementation of the U.S. Coast Guard's Differential GPS Navigation Service, USCG Headquarters, Office of Navigation Safety and Waterway Services, Radionavigation Division, 28 June 1993.

4. Final Report to the Lower Mississippi Vally Division DGPS Working Group - Establishing the Mississippi River DGPS Network, U.S. Army Topographic Engineering Center, 21 July 1993.

5. Update, LMVD Hydrographic Survey Work Group, (memorandum) Lower Mississippi Valley Division, Engineering Office, 8 March 1993.